

(12) **United States Patent**
Chien et al.

(10) **Patent No.:** **US 10,886,438 B2**
(45) **Date of Patent:** **Jan. 5, 2021**

(54) **MANUFACTURING METHOD OF LIGHT-EMITTING DEVICE**
(71) Applicant: **EPISTAR CORPORATION**, Hsinchu (TW)
(72) Inventors: **Jan Way Chien**, Hsinchu (TW); **Tzchiang Yu**, Hsinchu (TW); **Hsiao Yu Lin**, Hsinchu (TW); **Chyi Yang Sheu**, Hsinchu (TW)

(73) Assignee: **EPISTAR CORPORATION**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/239,153**

(22) Filed: **Jan. 3, 2019**

(65) **Prior Publication Data**
US 2019/0157513 A1 May 23, 2019

Related U.S. Application Data
(63) Continuation of application No. 15/371,834, filed on Dec. 7, 2016, now Pat. No. 10,211,373, which is a (Continued)

(30) **Foreign Application Priority Data**
Nov. 29, 2013 (TW) 102144302 A

(51) **Int. Cl.**
H01L 29/22 (2006.01)
H01L 33/44 (2010.01)
(Continued)

(52) **U.S. Cl.**
CPC **H01L 33/44** (2013.01); **H01L 33/22** (2013.01); **H01L 33/387** (2013.01); **H01L 33/405** (2013.01); **H01L 33/62** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

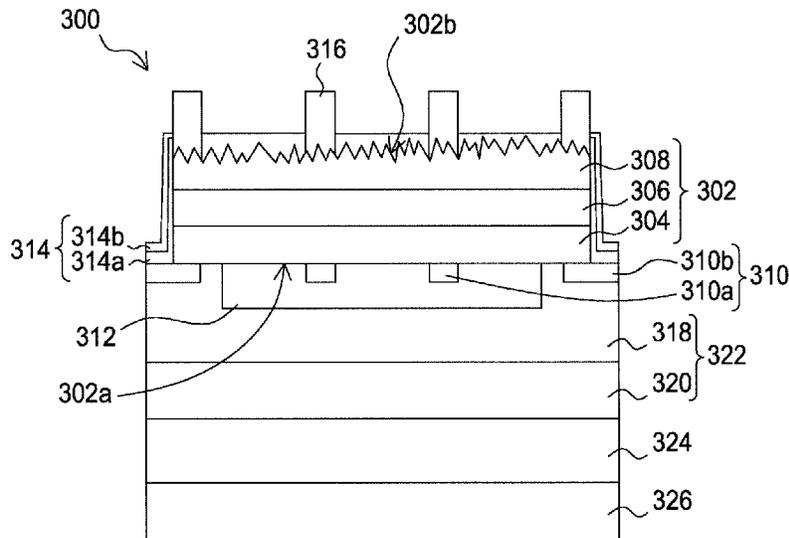
(56) **References Cited**
U.S. PATENT DOCUMENTS
8,004,006 B2 8/2011 Nakahara et al.
8,269,234 B2* 9/2012 Cho H01L 33/0079 257/103

(Continued)
FOREIGN PATENT DOCUMENTS
CN 102097569 A 6/2011
CN 102194929 A 9/2011

Primary Examiner — Hung K Vu
(74) *Attorney, Agent, or Firm* — Patterson + Sheridan, LLP

(57) **ABSTRACT**
A manufacturing method of a light-emitting device, comprising providing a growth substrate; forming a light-emitting stack on the growth substrate, the light-emitting stack comprising a first surface, a second surface opposite to the first surface, and a sidewall connecting the first surface and the second surface; forming a patterned dielectric layer on the first surface, the patterned dielectric layer comprising a first portion and a second portion separated from the first portion; attaching a permanent substrate to the light-emitting stack; removing the growth substrate after the permanent substrate is attached to the light-emitting stack; forming a plurality of trenches in the light-emitting stack to form a plurality of light-emitting units, wherein the plurality of light-emitting units are insulated from each other; and cutting along the plurality of trenches, wherein an outer part of the second portion of the patterned dielectric layer is thinned.

19 Claims, 4 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/555,746, filed on
Nov. 28, 2014, now Pat. No. 9,548,423.

- (51) **Int. Cl.**
H01L 33/40 (2010.01)
H01L 33/22 (2010.01)
H01L 33/38 (2010.01)
H01L 33/62 (2010.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,362,514 B2	1/2013	Hwang	
8,610,157 B2	12/2013	Choi et al.	
9,548,423 B2	1/2017	Chien et al.	
9,899,567 B2	2/2018	Jeong et al.	
2010/0163894 A1	7/2010	Uemura et al.	
2011/0133242 A1*	6/2011	Choi	H01L 33/38 257/99
2011/0198664 A1	8/2011	Kang	
2011/0284896 A1	11/2011	Park	
2012/0018765 A1*	1/2012	Mizogami	H01L 33/42 257/99
2013/0153950 A1*	6/2013	Mizutani	H01L 33/40 257/99

* cited by examiner

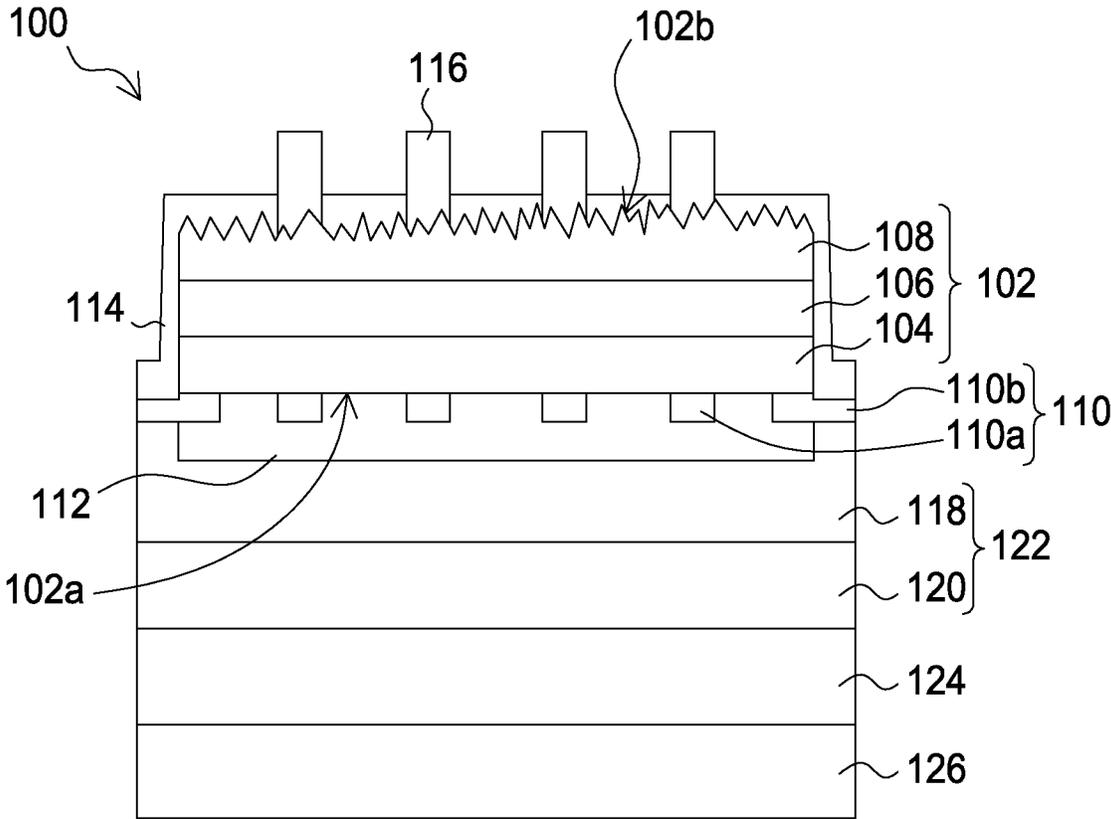


FIG. 1

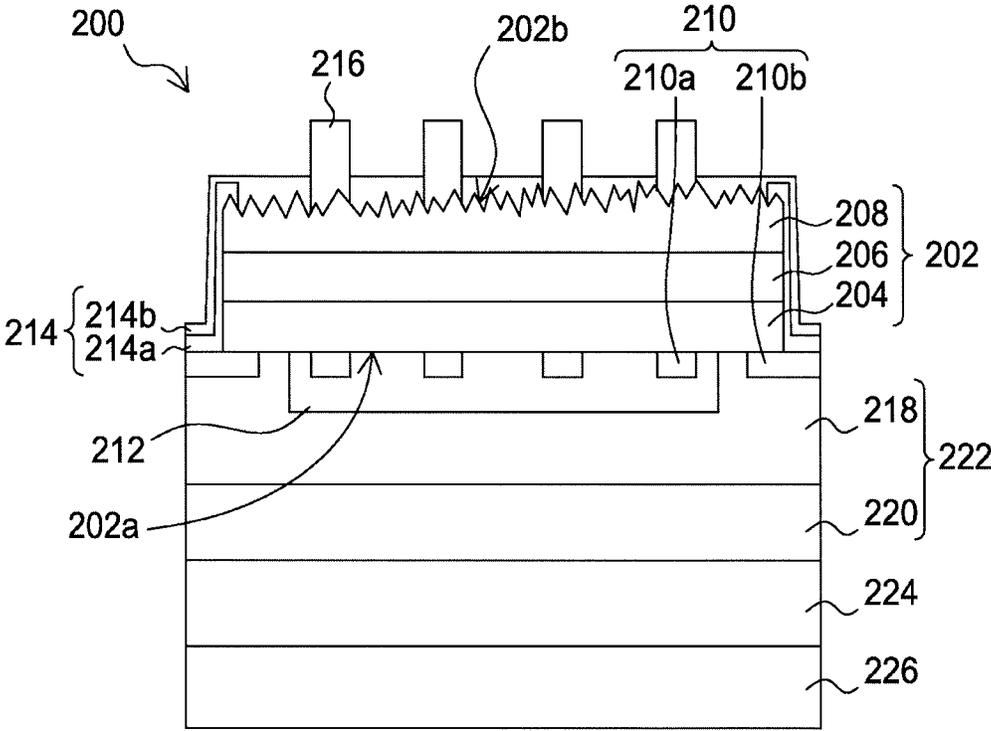


FIG. 2

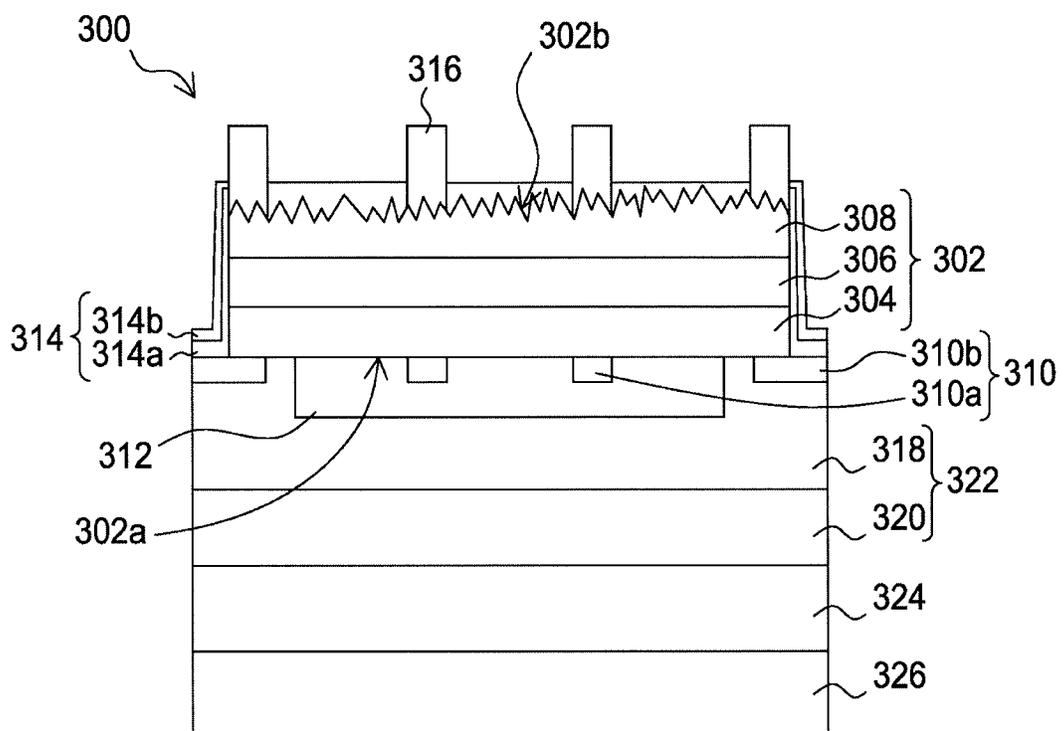


FIG. 3A

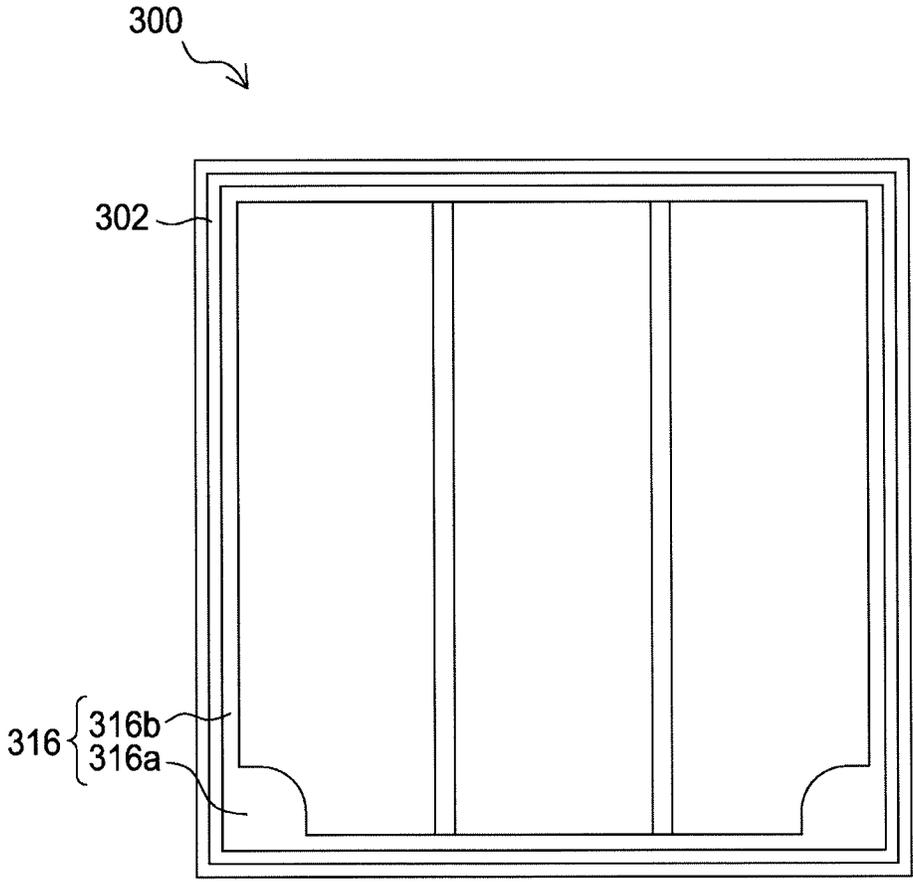


FIG. 3B

MANUFACTURING METHOD OF LIGHT-EMITTING DEVICE

REFERENCE TO RELATED APPLICATION

This application is a continuation application of U.S. patent application Ser. No. 15/371,834, filed on Dec. 7, 2016, which is a continuation application of U.S. patent application Ser. No. 14/555,746, filed on Nov. 28, 2014, now issued, which claims the right of priority based on TW application Serial No. 102144302, filed on Nov. 29, 2013, and the contents of which are hereby incorporated by references in their entireties.

TECHNICAL FIELD

The application relates to a manufacturing method of a light-emitting device, and more particularly, to a manufacturing method of a light-emitting device having a light-emitting stack located on a conductive substrate.

DESCRIPTION OF BACKGROUND ART

The lighting theory of light-emitting diodes (LEDs) is that electrons and holes between an n-type semiconductor and a p-type semiconductor are combined in the active layer to release energy. Due to the difference of lighting theories between LEDs and incandescent lamps, the LED is called "cold light source". An LED has the advantages of good environment tolerance, a long service life, portability, and low power consumption so it is regarded as another option for the lighting application. LEDs are widely adopted in different fields, for example, traffic lights, backlight modules, street lights, and medical devices and replaces conventional light sources gradually.

An LED has a light-emitting stack which is epitaxially grown on a conductive substrate or an insulative substrate. The so-called "vertical LED" has a conductive substrate and includes an electrode formed on the top of a light emitting layer; the so-called "lateral LED" has an insulative substrate and includes electrodes formed on two semiconductor layers which have different polarities and exposed by an etching process. The vertical LED has the advantages of small light-shading area for electrodes, good heat dissipating efficiency, and no additional etching epitaxial process, but has a shortage that the conductive substrate served as an epitaxial substrate absorbs light easily and is adverse to the light efficiency of the LED. The lateral LED has the advantage of radiating light in all directions due to a transparent substrate used as the insulative substrate, but has shortages of poor heat dissipation, larger light-shading area for electrodes, and smaller light-emitting area caused by epitaxial etching process.

The abovementioned LED can further connects to/with other components for forming a light-emitting device. For a light-emitting device, the LED can connect to a sub-carrier by the substrate side or by soldering material/adhesive material between the sub-carrier and the LED. Besides, the sub-carrier can further comprise a circuit electrically connected to electrodes of the LED via a conductive structure, for example, a metal wire.

SUMMARY OF THE APPLICATION

A light-emitting device comprises: a light-emitting stack comprising a first surface; a patterned dielectric layer formed on the first surface, comprising a first portion and a

second portion substantially surrounding the first portion and having substantially the same thickness with that of the first portion; a first reflective electrode covering the first portion of the patterned dielectric layer; and a barrier layer covering the first reflective electrode and the second portion of the patterned dielectric layer.

A light-emitting device comprises a light-emitting stack comprising a first surface, a roughened surface, and a sidewall connecting the first surface and the roughened surface; an electrode structure formed on the roughened surface of the light-emitting stack; a dielectric layer formed on the first surface of the light-emitting stack; a barrier layer covering the dielectric layer; a first reflective electrode between the barrier layer and the first surface of the light-emitting stack; and a passivation layer covering the sidewall of the light-emitting stack and the roughened surface of the light-emitting stack which is not occupied by the electrode structure, wherein the electrode structure is surrounded by the passivation layer, and the passivation layer contacts an surface of the electrode structure and terminates at the surface of the electrode structure.

A manufacturing method of a light-emitting device, comprising providing a growth substrate; forming a light-emitting stack on the growth substrate, the light-emitting stack comprising a first surface, a second surface opposite to the first surface, and a sidewall connecting the first surface and the second surface; forming a patterned dielectric layer on the first surface, the patterned dielectric layer comprising a first portion and a second portion separated from the first portion; attaching a permanent substrate to the light-emitting stack; removing the growth substrate after the permanent substrate is attached to the light-emitting stack; forming a plurality of trenches in the light-emitting stack to form a plurality of light-emitting units, wherein the plurality of light-emitting units are insulated from each other; and cutting along the plurality of trenches, wherein an outer part of the second portion of the patterned dielectric layer is thinned.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a light-emitting device in accordance with a first embodiment of the present application;

FIG. 2 illustrates a light-emitting device in accordance with a second embodiment of the present application; and

FIGS. 3A and 3B illustrate a light-emitting device in accordance with a third embodiment of the present application.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 illustrates a light-emitting device in accordance with a first embodiment of the present application. Light-emitting device 100 comprises: a permanent substrate 126; a lighting stack 102 formed on the permanent substrate 126 and comprising a first surface 102a toward the permanent substrate 126 and a second surface 102b opposite to the first surface 102a; a patterned dielectric layer 110 formed on the first surface 102a and comprising a first portion 110a and a second portion 110b approximately surrounding the first surface 102a, wherein the first portion 110a comprises a first thickness and the second portion 110b comprises a second thickness the same as the first thickness; a first reflective electrode 112 having reflectivity and covering the first portion 110a of the patterned dielectric layer 110, wherein the material of the first reflective electrode 112 can comprise

Ag, Al, or other metal having high reflectivity, or the sequence or alloy of aforesaid metal; and a barrier layer 122 covering the first reflective electrode 112 and the second portion 110b of the patterned dielectric layer 110. The second surface 102b of the light-emitting stack 102 can comprise a second electrode structure 116 comprising a pattern corresponding to that of the first portion 110a of the patterned dielectric layer 110. The first reflective electrode 112 ohmically contacts to the first surface 102a of the light-emitting stack 102, and the second electrode structure 116 ohmically contact to the second surface 102b of the light-emitting stack 102, and contact areas of the second electrode structure 116 and the first reflective electrode 112 do not overlap with each other in a vertical direction. A cross-sectional width of the barrier layer 122 can be slightly wider than the light-emitting stack 102, and the outer edge of the second portion 110b of the patterned dielectric layer 110 can approximately align with a side wall of the barrier layer 122 and project from a side wall of the light-emitting stack 102. A passivation layer 114 can cover a part of the second surface 102b of the light-emitting stack 102 that is not covered by the second electrode structure 116 by conforming to the shape of the light-emitting stack 102 and further cover a side wall of the light-emitting stack 102. The bottom of the passivation layer 114 contacts with the second portion 110b of the patterned dielectric layer 110. The material of the patterned dielectric layer 110 can comprise insulative oxide such as TiO₂ or SiO₂, insulative nitride such as SiN_x or AlN, or other insulative material like MgF₂. The material of the passivation layer 114 can comprise SiN_x or SiO₂. The material of the patterned dielectric layer 110 can be different from that of the passivation layer 114. In the embodiment, the material of the patterned dielectric layer 110 can comprise TiO₂, and material of the passivation layer 114 can comprise SiO₂ or silicon nitride (SiN_x or Si₃N₄). Without the second portion 110b of the patterned dielectric layer 110, the barrier layer 122 would directly contact the bottom of the passivation layer 114 and a portion of the first surface 102a. Since the material of the barrier layer 122 is usually metal, the adhesion with the passivation layer 114 is usually poor and a gap may be formed between the bottom of the passivation 114 and the barrier layer 122. In that case, the humidity or other outside disturbance may further affect the adhesion between the barrier layer 122 and the first surface 102a via the gap between the passivation 114 and the barrier layer 122. Once the barrier layer 122 is peeled off from the first surface 102a, the first reflective electrode 112 may be overflowed from the side wall of the light-emitting stack 102, and the risk of electric anomaly or function failure of the light-emitting device 100 is increased. In the embodiment, the first reflective electrode 112 further covers partial second portion 110b of the patterned dielectric layer 110 so the barrier layer 122 is not to be in contact with the first surface 102a.

The light-emitting stack 102 is grown from a wafer-level growth substrate (not shown) in advance, and after the patterned dielectric layer 110, the first reflective electrode 112, and the barrier layer 122 are formed, the first portion 110a and the second portion 110b of the patterned dielectric layer 110 are formed at the same time during fabrication process, therefore the material and thickness of the first portion 110a are the same with that of the second portion 110b. The permanent substrate 126 can attach to the light-emitting stack 102 by a connection layer 124, the barrier layer 122 can be between the connection layer 124 and the first reflective electrode 112, and the connection layer 124 can be between the barrier layer 122 and the permanent

substrate 126. The growth substrate can be removed after the permanent substrate 126 is attached to the light-emitting stack 102, and the second surface 102b can be a rough surface by using a method like dry etching. A plurality of light-emitting device 100 can be achieved by etching the light-emitting stack 102 to form trenches to form a plurality of units insulated from each other, and cutting the wafer along the trenches. The outer part of the second portion 110b is thinned when the wafer is cut, and the second portion 110b approximately remains the second thickness on a section contacts the first surface 102a.

The light-emitting stack 102 can comprise a first semiconductor layer 104, a second semiconductor layer 108, and an active layer 106 formed between the first semiconductor layer 104 and the second semiconductor layer 108, wherein the first semiconductor layer 104 can be p-type and comprises the first surface 102a, and the second semiconductor layer 108 can be n-type and comprises the second surface 102b. The barrier layer 122 can comprise a double layer structure comprising a first barrier layer 118 and a second barrier layer 120, and the material thereof can comprise Ti, W, Pt, TiW or the combination thereof. The light-emitting stack 102 can comprise single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH) or multi-quantum well (MQW) structure. The light-emitting stack 102 can be a nitride based light-emitting stack, and the material of the light-emitting stack 102 comprises one or more elements selected from the group consisting of Al, In, Ga, P, As, and N.

FIG. 2 illustrates a light-emitting device in accordance with a second embodiment of the present application. A light-emitting device 200 comprises: a permanent substrate 226; a lighting stack 202 formed on the permanent substrate 226 and comprising a first surface 202a toward the permanent substrate 226 and a second surface 202b opposite to the first surface 202a; a patterned dielectric layer 210 formed on the first surface 202a and comprising a first portion 210a and a second portion 210b approximately surrounding the first surface 202a, wherein the first portion 210a comprises a first thickness and the second portion 210b comprises a second thickness the same as the first thickness; a first reflective electrode 212 having reflectivity and covering the first portion 210a of the patterned dielectric layer 210, wherein the material of the first reflective electrode 212 can comprise Ag, Al or other metal having high reflectivity, or the sequence or alloy of aforesaid metal; and a barrier layer 222 covering the first reflective electrode 212 and the second portion 210b of the patterned dielectric layer 210. The second surface 202b of the light-emitting stack 202 can comprise a second electrode structure 216 comprising a pattern corresponding to that of the first portion 210a of the patterned dielectric layer 210. The first reflective electrode 212 ohmically contacts to the first surface 202a of the light-emitting surface 202, and the second electrode structure 216 ohmically contact to the second surface 202b of the light-emitting stack 202, and contact areas of the second electrode structure 216 and the first reflective electrode 212 do not overlap with each other in a vertical direction. A cross-sectional width of the barrier layer 222 can be slightly wider than the light-emitting stack 202, and the outer edge of the second portion 210b of the patterned dielectric layer 210 can approximately align with a side wall of the barrier layer 222 and project from a side wall of the light-emitting stack 202. A passivation layer 214 can cover a part of the second surface 202b of the light-emitting stack 202 that is not covered by the second electrode structure 216 by conforming to the shape of the light-emitting stack 202 and

further cover a side wall of the light-emitting stack 202. The bottom of the passivation layer 214 contacts with the second portion 210b of the patterned dielectric layer 210. The material of the patterned dielectric layer 210 can comprise insulative oxide such as TiO₂ or SiO₂, insulative nitride such as SiN_x or AlN, or other insulative material like MgF₂. The passivation layer 214 can comprise a first passivation layer 214a attaching to the second portion 210b of the patterned dielectric layer 210 and covering at least side wall of the light-emitting stack 202, and a second passivation layer 214b covering the first passivation layer 214a and the second surface 202b. The first passivation layer 214a comprises Si₃N₄ or SiN_x, and the second passivation layer 214b comprises SiO₂. In the embodiment, the first reflective electrode 212 and the patterned dielectric layer 210 is separated by a gap. The barrier layer 222 can comprise a first barrier layer 218 and a second barrier layer 220. A connection layer 224 can be formed between the barrier layer 222 and the permanent substrate 226.

FIG. 3 illustrates a light-emitting device in accordance with a third embodiment of the present application. A light-emitting device 300 comprises: a permanent substrate 326; a lighting stack 302 formed on the permanent substrate 326 and comprising a first surface 302a toward the permanent substrate 326 and a second surface 302b opposite to the first surface 302a; a patterned dielectric layer 310 formed on the first surface 302a and comprising a first portion 310a and a second portion 310b approximately surrounding the first surface 302a, wherein the first portion 310a comprises a first thickness and the second portion 310b comprises a second thickness the same as the first thickness; a first reflective electrode 312 having reflectivity and covering the first portion 310a of the patterned dielectric layer 310, wherein the material of the first reflective electrode 312 can comprise Ag, Al or other metal having high reflectivity, or the sequence or alloy of aforesaid metal; and a barrier layer 322 covering the first reflective electrode 312 and the second portion 310b of the patterned dielectric layer 310. The second surface 302b of the light-emitting stack 302 can comprise a second electrode structure 316 comprising a pattern corresponding to that of the first portion 310a of the patterned dielectric layer 310. The first reflective electrode 312 ohmically contacts to the first surface 302a of the light-emitting surface 302, and the second electrode structure 316 ohmically contact to the second surface 302b of the light-emitting stack 302, and contact areas of the second electrode structure 316 and the first reflective electrode 312 do not overlap with each other in a vertical direction. A cross-sectional width of the barrier layer 322 can be slightly wider than the light-emitting stack 302, and the outer edge of the second portion 310b of the patterned dielectric layer 310 can approximately align with a side wall of the barrier layer 322 and project from a side wall of the light-emitting stack 302. A passivation layer 314 can cover a part of the second electrode structure 316 of the second surface 302b of the light-emitting stack 302 that is not covered by the second electrode structure 316 by conforming to the shape of the light-emitting stack 302 and further cover a side wall of the light-emitting stack 302. The bottom of the passivation layer 314 contacts with the second portion 310b of the patterned dielectric layer 310. The material of the patterned dielectric layer 310 can comprise insulative oxide such as TiO₂ or SiO₂, insulative nitride such as SiN_x or AlN, or other insulative material like MgF₂. The passivation layer 314 can comprise a first passivation layer 314a attaching to the second portion 310b of the patterned dielectric layer 310 and covering at least side wall of the light-emitting stack 302,

and a second passivation layer 314b covering the first passivation layer 314a and the second surface 302b. The first passivation layer 314a comprises Si₃N₄ or SiN_x, and the second passivation layer 314b comprises SiO₂. In the embodiment, the first reflective electrode 312 and the patterned dielectric layer 310 is separated by a gap. The barrier layer 322 can comprise a first barrier layer 318 and a second barrier layer 320. A connection layer 324 can be formed between the barrier layer 322 and the permanent substrate 326.

As shown in FIG. 3B, the second electrode structure 316 can comprise at least an electrode pad 316a and an extensive-branch like electrode 316b, the second portion 310b of the patterned dielectric layer 310 overlaps the electrode pad 316a and the extension-branch like electrode 316b from a top view. The second portion 310b of the patterned dielectric layer 310 can comprise a boundary surrounding the light-emitting stack 302, and the second portion 310b comprises a width wider than that of the extensive-branch like electrode 316b, and the section overlapping the electrode pad 316a of the second portion 310b corresponds to the pattern of the electrode pad 316a.

The principle and the efficiency of the present application illustrated by the embodiments above are not the limitation of the application. Any person having ordinary skill in the art can modify or change the aforementioned embodiments. Therefore, the protection range of the rights in the application will be listed as the following claims.

What is claimed is:

1. A manufacturing method of a light-emitting device, comprising:
 - providing a growth substrate;
 - forming a light-emitting stack on the growth substrate, the light-emitting stack comprising a first surface, a second surface opposite to the first surface, and a sidewall connecting the first surface and the second surface, wherein the light-emitting stack comprises an n-type semiconductor layer, a p-type semiconductor layer, and an active layer formed between the p-type semiconductor layer and the n-type semiconductor layer, the first surface is a surface of the p-type semiconductor layer, and the second surface is a surface of the n-type semiconductor layer;
 - forming a patterned dielectric layer on the first surface, the patterned dielectric layer comprising a first portion and a second portion separated from the first portion, wherein the first portion comprises a first thickness and the second portion comprises a second thickness;
 - forming a first reflective electrode to contact the first surface of the light-emitting stack, wherein the first reflective electrode covers the first portion of the patterned dielectric layer, and the first reflective electrode is separated from the second portion of the patterned dielectric layer by a gap along a direction parallel to the first surface and the gap exposing the first surface of the light-emitting stack;
 - attaching a permanent substrate to the light-emitting stack;
 - removing the growth substrate;
 - forming a plurality of trenches in the light-emitting stack to form a plurality of light-emitting units, wherein the plurality of light-emitting units are insulated from each other; and
 - cutting along the plurality of trenches.
2. The manufacturing method of the light-emitting device of claim 1, wherein the first portion of the patterned dielec-

tric layer comprises the same material as that of the second portion and the first thickness is equal to the second thickness.

3. The manufacturing method of the light-emitting device of claim 1, further comprising etching the second surface of the light-emitting stack to form a rough surface.

4. The manufacturing method of the light-emitting device of claim 3, further comprising forming a passivation layer to cover the sidewall and the rough surface of the light-emitting stack.

5. The manufacturing method of the light-emitting device of claim 4, wherein the passivation layer comprises a first passivation layer covering the sidewall, and a second passivation layer covering the first passivation layer and the rough surface of the light-emitting stack, and the first passivation layer comprises a material different from that of the second passivation layer.

6. The manufacturing method of the light-emitting device of claim 5, wherein a first area of the rough surface of the light-emitting stack covered by the first passivation layer is smaller than a second area of the rough surface of the light-emitting stack covered by the second passivation layer.

7. The manufacturing method of the light-emitting device of claim 6, wherein the first passivation layer comprises SiN_x and the second passivation layer comprises SiO₂.

8. The manufacturing method of the light-emitting device of claim 4, further comprising forming an electrode structure on the rough surface of the light-emitting stack.

9. The manufacturing method of the light-emitting device of claim 8, wherein the passivation layer covers the rough surface of the light-emitting stack which is not occupied by the electrode structure.

10. The manufacturing method of the light-emitting device of claim 9, wherein the electrode structure is surrounded by the passivation layer, and the passivation layer contacts an surface of the electrode structure and terminates at the surface of the electrode structure.

11. The manufacturing method of the light-emitting device of claim 8, wherein the electrode structure comprises a first pattern corresponding to a location of the patterned

dielectric layer, wherein the patterned dielectric layer comprises a portion overlapping the electrode structure and comprising a width wider than that of the electrode structure.

12. The manufacturing method of the light-emitting device of claim 4, wherein the second portion of the patterned dielectric layer is connected to the passivation layer.

13. The manufacturing method of the light-emitting device of claim 1, wherein the first reflective electrode comprises Ag or Al.

14. The manufacturing method of the light-emitting device of claim 1, further comprising forming a barrier layer covering the first reflective electrode.

15. The manufacturing method of the light-emitting device of claim 14, wherein the barrier layer comprises Ti, W, Pt, TiW, or the combination thereof.

16. The manufacturing method of the light-emitting device of claim 14, wherein the barrier layer covers the first portion of the patterned dielectric layer and the second portion of the patterned dielectric layer.

17. The manufacturing method of the light-emitting device of claim 1, further comprising forming a barrier layer covering the first reflective electrode and filling the gap, wherein the first reflective electrode is between the barrier layer and the light-emitting stack.

18. The manufacturing method of the light-emitting device of claim 1, further comprising forming a barrier layer covering the first reflective electrode and the second portion of the patterned dielectric layer, wherein the second portion of the patterned dielectric layer comprises an outer edge approximately align with a side wall of the barrier layer.

19. The manufacturing method of the light-emitting device of claim 1, wherein an inner part of the second portion of the patterned dielectric layer contacting the first surface comprises the second thickness, and an outer part of the second portion of the patterned dielectric layer is thinned and comprises a third thickness formed by cutting along the plurality of trenches, and wherein the third thickness is thinner than the second thickness.

* * * * *